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TECHNIQUE OF GRASSLAND EXPERIMENTATION IN SCANDINAVIA AND FINLAND

A symposium on the technique employed in pasture studies, botanical analyses, etc.

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SUMMARY

The origin of the Swedish Grassland and Peat Association and an account of its experimental work are recorded. Research is described under two sections, technique for the quantitative measurement of grass production and technique of stock-grazing trials. The former involves trials by use of control cages and plot trials under specified cutting and grazing systems, while the latter involves records of dates for manurial treatments, times of pasturing, animal production, and data on grazing capacity and palatability of the sward.

The methods employed in Sweden for botanical analyses of pastures and long duration leys are described. They include field methods (notably the estimation of degree of covering by the Hult-Sernander method) and laboratory methods, involving sampling after cutting, separating and weighing the different species.

When areas on uncultivated, but otherwise productive soils are used for grazing in Norway, study is made of the most effective methods of utilization by means of cultivation experiments. Yield is determined in fodder units on the basis of number of grazing days and the amount of milk produced from stock on different plots. Yield is also determined in control experiments involving cutting under the following treatments : (1) fertilizing natural vegetation, (2) harrowing, seeding and fertilizing, and (3) complete cultivation, seeding and fertilizing. Draining experiments are also made and details are supplied from a trial at Løken, Vestnes. The fertilizer experiments described are based on two different principles involving (a) small plots from which the crop is cut, and (b) larger areas in which yield is determined also by grazing. The value of new strains for the different growing conditions of the country is measured by means of botanical analyses and determination of dry matter content. The scheme of pasture control on private farms is also discussed.

Methods of meadow experiments conducted at the experimental farms in Norway vary according to their objective and to local conditions. Tests of different species, strains and seeds mixtures, seeding rates, nurse crops, cutting times and fertilizers are included. Methods of botanical and chemical analysis are discussed and local meadow trials carried out in rural districts under the supervision of the State experimental stations are also noted.

Following the increasing importance of animal husbandry and forage crop production in Denmark, attention has been given to methods of grassland analysis. Details of the following are supplied : (1) P. Nielsen's method, (2) Raunkiaer's method, and (3) botanical weight analysis. Regulations and procedure prepared by the Government Experimental Department for Plant Culture for conducting strain trials with herbage plants are described, together with the technique for experiments on seeds mixtures.

Methods used in trials conducted in Finland from 1924 onwards in regard to grassland productivity include direct and indirect estimates. The norms employed in the northern countries for calculating pasture productivity, and modified to suit Finnish conditions, have been used by Charpentier in a method already noted (*Herb. Abstr.* 7. 288-9. 1937) and of which a brief account is given in the final article.

Giöbel, G. **Sweden**

TECHNIQUE EMPLOYED IN GRASSLAND AND PASTURE EXPERIMENTS OF THE SWEDISH GRASSLAND AND PEAT ASSOCIATION

Historical

While animal husbandry, particularly dairying, has for many decades occupied a prominent place in the agriculture of Sweden, grassland farming, on grass of a permanent type, has been of greater importance in the fodder production of the country during the last 25 years only. At the beginning of this century, rapid progress had been made along most lines of agriculture and especially in matters relative to dairying and the cultivation of field crops, but little attention had been given to the improvement of pastures. Hay was, and largely is still, obtained from temporary leys of timothy and clover and from natural meadows. A keener interest in pasture problems soon began to develop, however, and thanks to the pioneer work of a number of practical and scientific men, among whom Dr. A. Elofson of Uppsala is most prominent, experience on the improvement of natural pastures, and on the establishment and maintenance of permanent pastures on land formerly under crop rotation, was gathered in various parts of the country as well as in the neighbouring countries of Norway, Denmark and Finland, all being by location and inclination destined to base their agricultural production to a large extent on dairying.

Although in Sweden some attention had been given to hay and pasture problems by the Swedish Seed Association at Svalöf (founded in 1886), by the State Agricultural Experiment Institute at Experimentalfältet, and the Agricultural Peat Society of Jönköping (founded 1886), nevertheless it was deemed desirable to have an organization with the sole purpose of gathering evidence and spreading knowledge on these questions. To this end the Swedish Grassland Association was formed in 1916 by a number of agriculturists, and on the immediate initiative of Dr. A. Elofson, who, for many years, had worked for a more economic production of hay and grass crops, and was a close student of the agriculture of the Continent.

From January 1, 1939, the Agricultural Peat Society has for State financial reasons been amalgamated with the Grassland Association into a new organization, the Swedish Grassland and Peat Association. This is divided into two sections, one of which deals with grassland problems and the other with peat bog cultivation, both aspects being closely connected since peat lands in Sweden are particularly well suited for grass and hay crops. Financial support from the State is given to such extent at present that the Association approaches the position of a State institution, as is also the case with the Swedish Seed Association at Svalöf.

The main objects of the Association are to work for an economical production of hay and grass crops in general; to encourage a better utilization of the national resources of peat lands, natural pasture grounds and meadows by the introduction of rational methods for their management and cultivation ; to bring about enclosures

and the separation of pasture grounds from lands which can be used more profitably for forestry; to assist land owners and farmers in the preparation of plans for the establishment and improvement of their pastures, peat lands, etc. and to spread knowledge on these questions among the farmers.

In order to further this programme, the Association carries out extensive research and experimental work of a practical nature in the various sections of the country. The main objectives are to obtain as reliable information as practicable under the circumstances surrounding each project or system of experiments, and to incorporate into farm practice, as rapidly as possible, those findings which are considered sound from an economic point of view. In order to demonstrate the applicability of the results from exact experiments to actual farming conditions, extension trials on a larger scale are often used. This also has the advantage of bringing research workers in closer contact with farmers' problems in different localities and sections and thus assists in indicating the link between research and practice. In the following report it is intended to indicate briefly the principal methods adopted by the Grassland Section of the Swedish Grassland and Peat Association in determining the production of pastures.

It should, however, be stated in this connexion that, together with the work of the Association, experimental work on hay and grass crops is at present also being done to some extent by two other main institutions in Sweden. These are the Swedish Seed Association at Svalöf, dealing with breeding and strain testing work, and the State Agricultural College at Uppsala including the State Agricultural Experiment Institute at Experimentalfältet, which is the chief agricultural experimental organization in the country. The latter has so far done considerable work on hay crops of timothy and clover, etc. At present the Division of Animal Nutrition under the direction of Prof. H. Edin is planning experimental work with regard to pasture feeding problems on a broad basis, partly in collaboration with the Swedish Grassland and Peat Association. In addition to these institutions, the Plant Breeding Institute at Weibullsholm, Landskrona, should be mentioned.

Experimental procedure

The experimental work of the Association may be divided into trials for a direct determination of the quantity of grass produce, and trials for an indirect measurement of such produce by means of grazing animals, including combinations of the two processes.

Since the undesirable effects of continuous cutting of a pasture for several consecutive years has been observed and the necessity for maintaining the influence of the grazing animal on the sward—"the biotic factor"—has been demonstrated in Sweden as well as elsewhere, it has from the early period of experimentation been a matter of great importance to develop technical methods which will enable the experimenter to measure the grass produce under true grazing conditions, and which at the same time are simple enough to be carried through even in localities and places situated far from the central research institution. Among the various expedients that have been tried in the course of 20 years, the following methods of procedure may be mentioned.

1. Separating off for a longer or shorter period by means of movable fences certain sections of plots, the remaining portions of which were grazed.
2. Cutting certain portions of each plot immediately before and after grazing.
3. Laying out trials in two or more complete replications which are alternately grazed and harvested by cutting.

A. Technique for the Quantitative Measurement of Grass Production.

I. *Trials by use of control cages*

The method consists of using control cages or hurdles, made from boards and barbed wire, 4 × 4 metres in size, which are moved annually, or, if desired, after each grazing. Cutting can be made at each grazing time or at any interval desired. It has been found that the number of cages should not be less than four for each experimental moment as the mean error has been observed often to be somewhat high. This means, however, that the plots within which the cages will have to be moved from place to place must be fairly large. An experiment with several moments, therefore, tends to be rather large and the costs have been found to be excessive. Hence the method has been used to a limited degree and preferably in cases where an estimate of grass production has been desired in conjunction with the control of animal produce (pasture control) on larger folds. It has proved advantageous in testing the yield of pasture leys in harvesting hay for winter fodder.

II. *Plot trials on grazed folds with cutting certain portions before and after grazing.*

Plots are laid out preferably according to the row method, which possesses definite advantages compared with the usual checkerboard method, especially when machines are used for cutting. The size of the plot may be varied as desired, but 20 sq. metres (2 × 10 metres) has been found to be sufficient when the frame described below is used for sampling.

With this method no fences are needed. The experimental area is grazed simultaneously with the fold in which it has been laid out. Sampling or cutting is carried out on certain portions of the plots immediately before and after the beginning and end of the grazing. In sampling or cutting, which is done either by hand or by machine, the areas are constantly changed within the plot. Only a small portion of the total area of the plot is cut while the remainder is grazed and used for after-sampling. For the purpose of sampling, a frame with an inside area of 0.1 sq. m. has been used. Ten samples are taken at random for one yield determination and two or three such determinations are carried out for each plot.

The advantages of the method are that no fences are needed and that the harvesting of grass takes place under true grazing conditions, whereby it is also possible to study palatability questions.

The method has, however, from a practical point of view, certain serious drawbacks, among which the following may be mentioned. Owing to the absence of fences, sampling must take place promptly each time the fold is grazed. If the experimenter has supreme control of the grazing and if the place for experimentation

is situated near the central research institution, it is a comparatively easy matter to handle the work. In all other cases practical difficulties are likely to be met. The method is therefore not suitable for experiments which have to be carried out in large numbers and spread over different localities to ensure testing under different soil and climatic conditions, as is usually the case with manuring trials. Difficulties of a practical nature are sometimes also encountered when two or more groups of animals are grazed consecutively. Another drawback is due to inequalities (caused by the droppings of the animals) which are apt to result in considerable disturbances after each grazing. In the case of manuring experiments, this leads to a certain levelling out of the effects of the fertilizers under test as will be discussed more fully below. The method, as outlined above, fails to give any measure of the grass growth obtained during the actual time of grazing, that is, between the first and the second sampling.

This method has been used with advantage in trials with seeds mixtures and varieties and also when matters regarding palatability are in question. The frame has also been used for estimating grass production and for obtaining samples of the grass in manuring trials with grazing animals (as described below under B) where on folds of 0.5 hectare, four determinations are made each time the animals enter and leave the fold in question.

III. *Trials with alternate cutting and grazing.*

This method is a modification of the old cutting trial method. Instead of cutting for several consecutive years, cutting and grazing are carried out in alternate years. With this method it has been found advantageous to lay out the trials with two or three replications which are alternately cut and grazed. With three replications (each with the same number of plots) one can be cut each year, while cutting and grazing can alternate on the other two : or two replications can be grazed every year, while one is cut. As a rule, however, satisfactory results are obtained with annual alternation.

Comparisons have been made between continuous cutting and the alternation of grazing and cutting, and results with the same implication have been obtained. On the average, data from a large number of manuring experiments over a period of six years point to the conclusion that the yield has been raised by 20 to 30 per cent through alternation. This has been found to be particularly striking for unmanured, or only moderately manured moments, where the increases as a rule are considerably higher than on well-manured moments. The results therefore show clearly that repeated cutting during a long period leads to an intensification of the effect which fertilizers exert, while with grazing the opposite happens, or a certain levelling out takes place. All this is connected in the one case with the removal from the trial of the cut grass and in the other with the influence of the grazing animals, and of course more particularly with the direct restoration of the greater part of the plant nutrients which the animals had absorbed with the grass. The unmanured moment, which in itself gives considerably less pasture to the animals than the manured moments, receives as large an amount of droppings as the others, and is therefore particularly favoured by the grazing, on account of which equalization occurs. Through the

alternation of grazing and cutting the results should, however, be broadly representative.

One drawback which always accompanies the grazing of a trial lies in the inequalities caused by the droppings of the animals. If spreading of the excrement be carried out carefully and immediately after each grazing, the effects are, however, reduced to the minimum. It is not possible to weaken the effect of urine, but it disappears relatively quickly, and even during the winter following, the grazing has been somewhat diminished. It is in fact only the first cut in the spring which is affected by the droppings.

The main advantage of this method is found in the fact that, owing to the fence around the section of the experiment which is to be cut for the particular year in question, harvesting can take place at times decided upon by the experimenter, and be carried out independently of the grazing of the surrounding fold, the care of which is left to the farmer himself. This makes it possible to carry on simultaneously a large number of experiments spread over various sections of the country representing different conditions with respect to soil and climate, etc. Approximate dates for harvesting can be fixed beforehand so that, by the aid of assistants stationed in the more important regions, it is possible to obtain results which on the whole will be fully comparable. Practically all plot experiments on manuring and liming questions carried out by the Association have been laid out according to this method.

IV. *The lay-out and management of experiments under alternate cutting and grazing technique.*

The checkerboard method or the row method may be used according to circumstances. Both are being employed, but the former most frequently with plots of 25 square metres (5 × 5 m.). Most new trials are laid out according to R. A. Fisher's system with blocks, as this appears to facilitate the carrying out of a number of experimental combinations, for example, liming and the application of farmyard and other manures. Usually four replications are used. The latin square is being used whenever possible in regard to the number of treatments involved. The size of the experiment is governed by practical considerations and is such that under the least favourable seasonal conditions (autumn) the whole of the plots of one section can be cut and weighed in the time available on half a day, or one day. Random distribution of plots has not hitherto been practised.

Most experiments are carried on for periods of four or six years. Each section of the experiment will then be cut twice, or three times. The marking of the plots is therefore done so that it will remain for such a period. Wooden pegs as a rule last only one year and are not always safe. Hence, furrows, approximately 7 cms. in top width, are dug along all borders. These furrows last on mineral soil generally for the period indicated. On peat soil, they have to be renewed every three years or so.

Cutting of the experiments is done five times in the course of the season, namely, at the end of May, middle of June, July and August, and finally at the end of September or beginning of October. In seasons with normal conditions this programme may

be carried through without difficulties. Drought periods may, however, upset the programme occasionally or locally. In wet seasons an extra cut may be taken. It is always desired to obtain the same number of cuts from all trials belonging to a certain category so that results may be mutually comparable. Cutting is done by means of scythes within 2 to 3 centimetres from the ground. As a rule there is no difficulty in finding men skilled in use of the implements. In order to minimize errors, cutting is not done as a rule until the herbage is fairly free from moisture. Exceptions to this rule occur, however, frequently in the case of the last harvest in the autumn.

Weighing and recording of the herbage are done immediately following the cutting of one plot. At the same time samples of 200 or 500 grams net of green weight are taken from each treatment (but not from each replication of plots). These are immediately dried in the sun or in the laboratory at temperatures not above 40°C. and later used for determinations of percentage hay and dry matter. They also furnish material for chemical analysis as desired. In former years determinations of crude protein contents have been made ; also in many cases of crude fibre and of phosphorus and calcium.

From two cuts, that is, those taking place in June and in August, samples of approximately 500 grams fresh weight are taken from two series of plots of each treatment for botanical examination. Such sampling is done immediately after cutting and before weighing. These samples are sent to the botanical laboratory of the main institution for immediate separation into three main groups of plants : clovers, grasses and miscellaneous plants. This is done by young girls under the supervision of well-trained botanists, who record the fresh weights, make notes of the main constituents of the groups and also roughly estimate their proportion within the groups. In addition to this, notes of the density of the sward, etc. are made at times for cutting or at least once a year. Notes are also made from the sward of the section which is being grazed and the manurial droppings from the grazing animals are carefully spread in order to minimize the after-effects during the following year. Roughages of left herbage are cleared away.

Early in the spring before vegetation sets in, fences are moved from one section to another. In this type of experiment it is always necessary to have fences made strong in order to withstand any pressure from the animals. As a rule three lines of barbed wire are used. Two lines may also prove to be sufficient provided that the poles are strong and not more than 5 metres apart.

B. The Technique of Stock Grazing Trials.

When grazing trials were initiated in 1926, two possibilities presented themselves, namely, the setting up of trials with a separate animal group for each moment of trial (the group system) or with only one animal group which was allowed to graze all the moments of the trial (the periodic system). Although the former method appeared to be better and more thorough, the latter method was chosen as the more practical, assuming that adequate areas and animal groups of equal value could be procured. The use of milking cows was deemed desirable since dairying is of primary

importance in Sweden. Fattening of stock for the market is not common and sheep are scarce. Thus high-yielding milking cows, young stock and eventually horses (mostly employed for after-grazing) constituted the animal groups utilized. Young cattle have been used for after-grazing in a few instances instead of horses.

The trials are designed to measure the time which the animal group requires to graze the different folds, when the intensity of grazing on all remains the same, and to control as carefully as possible the production of the animals. Provided that high yielding milk cows (which thus are sensitive to any changes in the feeding) are selected for the group, it is a comparatively simple matter to determine any eventual changes in the milk production towards the end of the grazing of one fold and to arrange accordingly for transference to the next. The higher the cows are in the scale of milk production the more definitely will they register any changes in the quantity and quality of the herbage in the fold. In proportion to the non-occurrence of such changes, the grazing time in the first place gives a relative measure of the supply of grass on the different moments. Through production control it is possible to examine the results in detail and to express them in terms of grazing days, kg. milk, live weight or food units per hectare.

The following data are recorded in the trials :

I. Dates for carrying out manurial or other treatments according to the plans of the experiment.

II. Grazing dates, including the exact time of pasturing the animal group in one fold or of the transference from one fold to another.

III. The production of the animals :

1. Yield of milk per day from each cow ; individual records being made for each milking time. Determinations of percentage of fat in the milk at regular intervals of 15 or 21 days.

2. Live weight of animals is determined :
   a. at the end of the feeding period in the byre,
   b. 10 days after grazing commences,
   c. subsequently once every 30 days,
   d. at the end of the total grazing periods,
   e. 10 days after feeding in the byre has begun,
   f. animals eliminated from the trial are weighed on the date of such elimination.

IV. Number of grazing hours for horses and specification of horses' age.

V. Specification of any extra fodder required when animals for special reasons are temporarily removed from the trial. During drought the group may have to be transferred temporarily to other pasture grounds.

VI. Any notable changes in the well-being of the animals, etc.

VII. Notes on extreme weather conditions which may affect animal production, and records of meteorological data.

VIII. Notes on grazing capacity and palatability of the sward ; dates for spreading of droppings, etc.

In connexion with most trials determinations of the quantity of grass produce has been ascertained according to the methods described under A, that is, by means of control cages, by the frame method and, in the more recent trials, by means of experiments with alternate cutting and grazing within the area of one or two of the folds.

Botanical examination and chemical analysis of the herbage are made in conjunction with these determinations.

From experience so far obtained, the following points are of importance :—

1. Trials with animals are most suitable in investigations where a distinct result is to be expected from the treatments carried out. Hitherto this method has been used only in connexion with nitrogenous manuring tests in which great differences occur between the systems.

2. Only a small number of moments should be included. The Society's earlier trials comprised three moments with two replications, but the most recent trials contain two moments with three replications.

3. The grazing areas are divided into experimental folds and should be as uniform and homogeneous as possible so that the folds are of equal value, not only as regards soil and botanical conditions, but also as to situation, slope of the ground, watering facilities, etc.

4. The fold should be at least 0.5 ha. or preferably 0.8 to 1.0 ha. in size. In the most recent trials of the Society folds of 0.9 and 1.3 ha. are used.

5. For the experimental group, older, quiet milk cows giving a high yield should be selected. Sick and bad-tempered animals must be exchanged immediately or removed from the group.

6. The size of the experimental group should be calculated according to the productive capacity of the ley in question. The cultivated pasture leys on which the Association's trials were laid out showed generally a yield of 2,500 to 3,500 food units per hectare, and on these leys it was found suitable to begin in the spring with five cows per hectare. The weather during the spring can of course exert an influence. The number of cows is subsequently reduced in relation to the supply of herbage during the later stages of the vegetative period.

7. The sequence of grazing the experimental folds should be the same throughout the trial if possible. Grazing begins when the supply of grass in the spring is the earliest or most plentiful ; in the Society's trials this occurs on the folds most heavily manured with nitrogen. The number of grazings should normally be about six to seven per season, and the period during the early part of the summer should be much shorter than during the latter part of the summer.

8. In determining the most suitable time for moving the animal group from one fold to another, the degree of grazing should be taken into account in the first place, together with milk yield. When a tendency to decline is noted, moving should not be delayed. The change should be made immediately after measuring the milk yield. Any grass remaining can be grazed by horses.

9. Trials of this kind should extend over many years, at least a five-year period, when errors which may arise owing to animal variation, changing weather conditions,

variations in degree of grazing, etc., are materially reduced. Further, it is desirable that the trial should be under the management and supervision of the same personnel during the whole period of the trial.

10. A combination of animal trials with measurement of grass production on various folds appears to be particularly desirable under all conditions. In the trial hitherto conducted by the Society, grass production has been measured by cutting the control cage areas, and also by taking samples according to the frame method before and after each grazing. In the most recent tests the animal trial has been combined with a large plot trial involving alternate cutting and grazing which, to make the investigation complete, comprises several moments apart from the two included in the animal trial.

As is evident from what has been stated above, the possibilities of carrying out the experimental method with grazing animals (dairy cattle) are very restricted. The places where large trials of such a kind can be conducted during a course of years are relatively few, and the method is therefore not adopted for "local" trials in the ordinary sense, although such trials are of considerable interest from the demonstration point of view. The greatest value and merits of the method lie in the fact that the trial is carried out under the conditions obtaining in practice on relatively large areas, and that the quantities which are measured are precisely the products which are obtained in pasturing and which possess an economic value directly determinable. From the farming point of view it is, therefore, undoubtedly a matter of importance that the technique of stock grazing trials should be more fully developed and improved. It seems that the recent introduction of the electrically charged wire for fences should be of considerable aid in this direction, since the use of such fences would greatly facilitate varying arrangements of folds and enclosures of a movable type.

Since the economic value of a certain treatment cannot possibly be judged from the results of any single experiment it may be well to emphasize again the desirability of carrying out any investigation on a broad basis with a sufficiently large number of experiments, laid out under a wide range of soil and farming conditions and continued over a period of years with varying climatic conditions. Experience has shown that in Sweden rainfall exercises a far greater influence on results than any other factor and that the manifestation of results may vary considerably in relation to climatic conditions.

It should also be borne in mind that the question whether a practice is economic or not is always influenced by the personal element and by former and present management.

Karl Lundblad **Sweden**

METHODS FOR BOTANICAL ANALYSES

Botanical analyses are necessary in grassland and pasture experiments, at least in the case of pastures and long duration hay leys. Such leys are especially common in those parts of the country (northern Sweden) where, because of climatic conditions, very few other crops can be grown. Especially is this the case on peat soils. Even in other parts of the country grassland plays a more important role on peat than on any other soil type. This is probably the reason why most of the methods used for botanical analyses were first worked out, or at least adopted for grassland experiments, by the botanists of the Swedish Peat Society (Svenska Mosskulturföreningen). Robert Tolf, the first botanist of that Society, began botanical field analyses about 1890, and a few years later he also started laboratory analyses. In principle his methods were the same as some of those still used.

The most accurate way of analysing botanically the crop from a grassland or pasture experiment is to separate each species and then to weigh them either in their natural condition or, more suitably, after drying. In ordinary field experiments this can be done only on small samples taken from the whole crop of the experimental plots. Analyses of this type, however, take a long time, and therefore we often make laboratory analyses only of one sample from each treatment in the experiment. For this reason it is necessary to inspect the experiment in the field before cutting and, at least where differences seem to occur between plots of the same treatment, to make field estimates of the composition of the herbage in each plot. Sometimes—if the herbage is composed of practically only one species—laboratory analyses may be unnecessary. For several reasons, estimates in the field, if possible combined with a simplified analysis, may be sufficient in many cases. The methods where the " analysis " consists of a direct estimation in the field are here called field methods. All other methods are designated laboratory methods.

Field Methods

The most desirable method for botanical analysis would naturally be a field method enabling direct estimation to be made of the percentage of each species in the crop which is to be harvested after estimation. Unfortunately no such method can be sufficiently accurate except in special cases. Even if the accuracy of methods of the type mentioned is not very good, they are used in many of our experiments. In the so-called local fertilizing experiments, that is, the numerous tests carried out on farms all over the country by local agricultural authorities under the supervision of the State Agricultural Experiment Institute, it is generally not possible to use an elaborate field method or a method of the laboratory type. The reason is that the field assistants have large districts and numerous experiments to manage. Estimation of the composition of the herbage in these grassland experiments is

simplified by the fact that the seeds mixtures used are fairly simple. They consist often of only one legume and one grass species, namely, red clover and timothy. Sometimes, naturally, there may be other species sown, but in any case it is most important in such experiments to obtain an estimate of the clover percentage. As a rule such estimates, for instance, of the percentage of red clover in the crop, are not made more exact than to within 10 per cent of the total crop. In fact they may not be reliable even to this extent.

Because no really reliable way can be found of estimating the weight percentages of the components in the herbage, we do not use such estimates except in the cases mentioned. The field methods used in other experiments are nearly always founded on an estimate of the degree of cover for each species. Methods still easier to handle are those which aim only at a measure of the rate of frequency of the species. Such methods involve in fact nothing but an estimation of the average distance between individuals of the same species and a false opinion of the quantitative composition of the herbage is thus obtained. These methods are, therefore, rarely used in Sweden.

When estimating the degree of covering, that is, the part of the total area in a plot covered by a certain species, one may naturally use any limits between the different degrees. It would seem that a direct estimate of the percentage cover of each species is most convenient, and this procedure is also used by some investigators. It will be found, however, that the practical application of such a method is rather difficult. Especially is it difficult to make an estimate of this type when the degree of cover is high. For instance, it is hardly possible to say, at least with any claim to accuracy, whether a certain species occupies, for example, 80 or 90 per cent of the area. It is far easier to estimate if the covering is about 10 or 5 or less than 5 per cent. If the herbage contains several species of a similar type, for instance different species of grasses, it is easier to compare the degrees of covering of these species than to estimate the covering of each species separately. This is one of the many advantages of the Hult-Sernander method, proposed about 60 years ago by R. Hult for plant sociological purposes. Later it was further developed by R. Sernander. Since then it has been most commonly used by Swedish botanists for studies of natural plant communities. For practical grassland studies it was applied by the botanists of the Swedish Peat Society and it was practically the only field method used in those investigations. Now the same method is also used in the grassland work at all our State experimental farms.

There are three main points to observe in this method. Firstly, all the species are divided into different " ground forms ", that is, main types of growth habit, for instance, trees of different types, grasses, herbs, lichens and so forth. Secondly, different strata of the vegetation are distinguished, namely, tree, shrub, field and ground strata. Thirdly, the area covered in each stratum by different ground forms of plants, and different species within each ground form, is estimated. This estimate is made in the following way. All parts of the plants (in their natural position in the field) are visualized in projection on a horizontal plane. Then the total of the area thus occupied in a certain stratum by each species or group of species is estimated.

In grassland work the only ground forms of any special interest are grasses, miscellaneous herbs, and, sometimes, mosses. The only strata occurring are field and ground strata. Three field strata are distinguished according to the height of the plants in the original method. For grassland studies, however, it is more convenient not to maintain the precise limits between these strata. This will be clearly understandable if we consider the differences in height of the same species under different conditions, for instance under different fertilizing or varying natural fertility of the soil. Sometimes it may be better to use four field strata. In any case the limits between the different field strata must be suited to the circumstances.

Originally Hult distinguished between 12 different "degrees of covering", but in his publications he reduced the degrees to 5 only. There have been different interpretations of the limitations of these degrees. Those given by Sernander are most commonly used. For grassland studies these limitations are also used at present. The degrees of covering are expressed by the figures 1 to 5. The meaning of these figures is as follows:

5: more than half the area is covered
4: 1/4—1/2 of the area is covered
3: 1/8—1/4 ,, ,, ,, ,, ,,
2: 1/16—1/8 ,, ,, ,, ,, ,,
1: less than 1/16 of the area is covered.

Often a + or a — sign is added after the figure in order to indicate whether the degree of covering is nearer to the upper or lower limit respectively.

An interesting question is the extent to which field analyses give an idea of the quantitive composition of the herbage. There is no direct relation between the degree of covering and the weight percentages of different plants in the herbage. There are several reasons for this. It is obvious that, for instance, a broad-leaved herb has a higher degree of covering at a certain volume and weight than an upright narrow-leaved grass. Thus a tall grass, for example, timothy, may form a big percentage of the quantity even if it covers only a lesser part of the area, whereas a plant such as white clover may cover practically the whole area and still form only a small part of the total crop if there are other species present. Even for the same species no direct relation can be expected between covering and volume or weight. The degrees of covering obviously depend to some extent on the surface area of the plant. They represent functions of the second degree. Volume and weight are functions of the third degree. If we express graphically the relation between the degrees of covering and the percentages of weight for a certain species we must, therefore, expect to get a curve of a parabolic shape. Further, the sloping of the curves for different plants must differ in accordance with the type and shape of the plants. The author has made a comparison between the results of field estimates according to the Hult-Sernander method and from botanical analyses of the hay. About 1,500 botanical hay analyses and 6,000 field estimates from the same plots were used for this investigation. The results agreed very well with the ideas expressed above. At the same time they showed that reliable results which may be reproduced can be obtained by this field method.

Though the method does not give direct information about the quantitative composition of the herbage, it is very valuable. In fact it gives a better idea of the density and general appearance and composition of the herbage than any other method. For grassland investigations it has the advantage of being reliable and at the same time rather rapid, provided the investigator has a good knowledge of flora and skill in use of the method. Even when botanical hay analyses are made, it is advisable to include such field investigations. Analyses can very often be made only on a few samples, perhaps only one sample for each treatment in an experiment. The individual variation within the plot and between different plots of the same treatment will not be registered and in any case the analyses do not give an idea of the general appearance of the herbage when growing. Therefore both field estimates and hay analyses are made on the experiments at our experimental farms.

The estimations according to the Hult-Sernander method on grassland experiments are most conveniently made when the plants have reached their full vegetative development, that is, at or immediately before flowering time. In the case of grassland for hay production we therefore make the estimations just before cutting. The method can naturally be used on pasture experiments also, and requires only an investigator skilled in the determination of plants in the vegetative condition. But the estimates will, necessarily, take more time and yet be less accurate in such cases. Field estimates in pasture experiments, therefore, are often confined to an estimate of the degree of covering of white clover. For the cases where a more thorough investigation seems desirable, laboratory analyses are used.

Laboratory Methods

The main point when using a laboratory method is to obtain a really representative sample of the plot or plots to be analysed. Some investigators have used a special method for this purpose. Several small sample plots were laid out at random within the experimental plot. The herbage on the sample plots was taken for analysis before cutting the rest of the area. This method is rather laborious because many sample plots are necessary if a reliable idea of the average composition of the whole experiment plot is to be obtained. Therefore we generally take the samples after cutting.

When sampling the cut herbage, it is important that no preconceived opinion of the composition is held. The samples should be taken without any postulate about the result of the analyses. We have found that the best way is to cut the whole sample plot without raking the crop together. Immediately after the cut, small samples of the same size are taken at regular intervals from the whole area. These small samples are put together and thus form the sample for analysis. The number and size of the small samples necessary to obtain a joint sample representative of the whole plot depend mainly on the homogeneity and size of the plot. For most purposes a sample for analysis of a grass-clover mixture cut for hay should not weigh less than about 1 kg. If smaller samples are used the results of the analyses may be unreliable. When the experiment plots are large there will be big joint samples and by this method of sampling the analyses take too much time. In

such cases the joint sample is thoroughly mixed and a convenient part of it is taken for analysis. When cutting at an early stage of development, for example, in pasture experiments, a much smaller sample can be taken than in the case of a hay crop because of the lesser weight of the fine leaves and the small plants forming the herbage.

The analysis consists in sorting out and weighing the different species. One may make total analyses, which means that all the species present are sorted and weighed separately, or partial analyses where only one or a few species of special interest for the experiment in question are sorted from the bulk of other species. In any case it is necessary that even small specimens of the species to be analysed are selected and correctly determined. This demands, of course, a skilled operator.

Partial analyses are sufficient in many cases, for instance, when comparing different strains of the same species. Thus such analyses are commonly made at our plant breeding institutions and also when testing different strains at the experimental farms. In the case of pastures it may often be sufficient to determine by a weight analysis the percentage of white clover and to sort out all other species into two main groups, grasses and other plants. Within these groups the components are determined by an estimate only. This has been the common procedure at the Swedish Grassland Association (Svenska Betes- och Vallföreningen) and also in many cases at our experimental farms. In many types of fertilizing experiments the same type of analyses may be sufficient. Very often, for instance, it is desired to determine the influence of the fertilizers on the percentage of clover. Where different treatments of the experiment plots are repeated year after year, for example, in "repeated experiments" with different cutting times or different fertilizing, the influence on the composition of the herbage may be very marked and affect several of the components. In such cases total analyses will be necessary.

It has been much discussed whether the botanical analysis should be made on the hay or on the clover and grass immediately after cutting. Both methods may be considered equally good provided the samples are carefully handled and stored. A skilled operator determines the dry plants just as easily as the fresh ones. Thus it is important that no losses of fine leaves etc. occur when drying and storing the hay. In the case of simple analyses from a small experiment, selection and even weighing may be made on fresh samples. This is often done in pasture experiments. In the numerous grassland experiments at our large experiment farms this method is impossible. It would demand many skilled analysts. Therefore the samples are dried either in the field or, where possible, in special drying machines and the analyses are made in the laboratory afterwards.

Bjarne Sakshaug **Norway**

TECHNIQUE OF GRASSLAND PLOT AND FIELD TRIALS IN NORWAY METHODS OF PASTURE EXPERIMENTS

Cultivation Experiments

In Norway pasture and grazing lands are generally laid down on uncultivated ground. An important task in connexion with questions affecting the development of Norwegian pasture lands has so far been a study of the methods which are most effective and economical when areas on uncultivated, but otherwise productive soil of varying quality and substance are to be used for grazing purposes.

The experiments which were carried on to solve this problem were first made on small areas divided into squares of about 25 sq. m., generally arranged in two or three plots of equal size for each treatment. The crop from these plots was generally cut as pasture grass twice each summer, and the yield of fresh grass alone was determined. The different methods of cultivation were often combined with different experiments in fertilizing and liming, involving up to eight or ten different treatments of a varying nature. In recent years comparatively large plots have been used in the experiments on cultivation for pasture, and the different trials cover sufficiently large areas so that yield, after the different treatments, can be determined through grazing. We have now adopted methods involving a less complicated technique. In most cases only three experiments are used without replications, for instance : (1) fertilizing natural vegetation, (2) harrowing, seeding and fertilizing, and (3) complete cultivation, seeding and fertilizing. Some experiments cover only the first and second of these alternatives. The area devoted to each treatment ranges from 0.3 to 1 ha. The size of the experimental areas therefore varies from 0.6 to 3 ha. Most of these experiments cover about 1 ha. and the cost of each cultivation method is determined as accurately as possible.

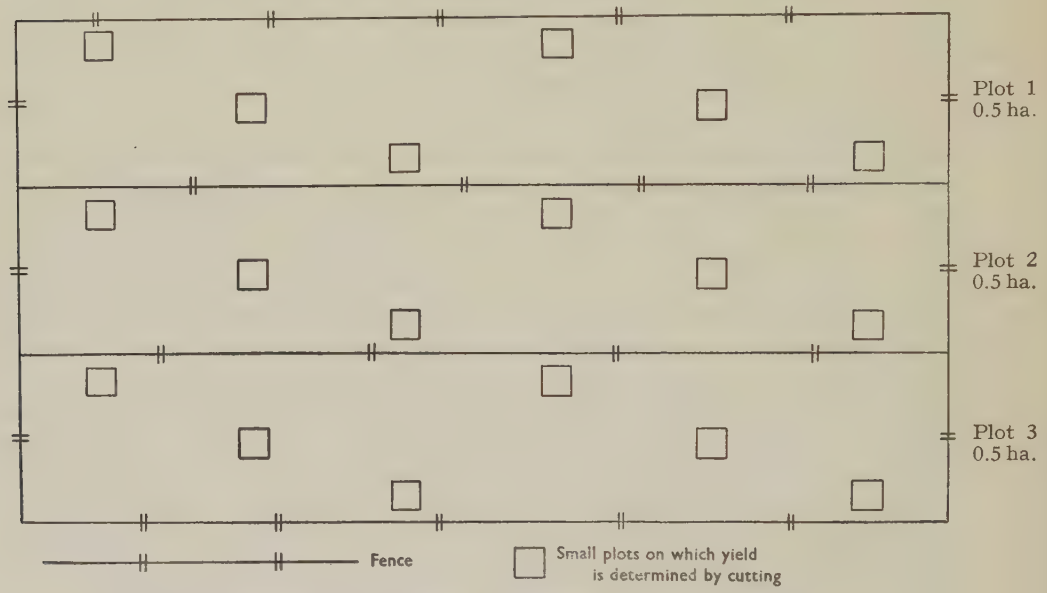
For grazing, one group of animals is used and is moved from one plot or treatment to the other (" the period system "). The yield is determined in fodder units on the basis of number of grazing days and the amount of milk produced on each plot. For the purpose of calculating the fodder units, the standards worked out by the Association of Agricultural Researchers in the Northern Countries are used. As it is impossible to determine the live weight increase of the animals each time they are moved from one plot to another, this increase is determined for the entire grazing period. The daily increase in weight is calculated, and the different treatments are credited with this increase in relation to the number of grazing days on each plot (treatment). The animals used in these grazing experiments are preferably dairy cows, but young cattle are also included to a certain extent. When dairy cows are used, the amount of milk is determined by daily weighing or measurement.

In order to control the accuracy of the calculations based on the above-mentioned grazing trials, special plots are reserved in most of these experimental areas, in which the grass is cut several times during the summer, and the yield determined by weighing. In most cases the dry matter of the grass is determined, but sometimes the yield of fresh grass alone is obtained. These plots are fenced and tests are generally moved to a new part of the experimental area each year.

The following plan is an example of how such a cultivation experiment has been laid out at the Maere Agricultural School at Sparbu, a short distance north of the city of Trondheim, in the province of Nord-Trøndelag.

Fig. 1

Plan for cultivation experiment on moorland at Maere Agric. School, Sparbu.



Plot 1.—Fertilizing only, on natural vegetation.
Plot 2.—Harrowing, seeding and fertilizing.
Plot 3.—Complete cultivation, seeding and fertilizing.

Each experimental plot consists of 0.5 ha. The fenced plots upon which the yield is determined are 25 sq. m. in size and they alternate from place to place, according to a definite plan.

Young cattle are used as grazing animals, and they are periodically changed from one grazing plot to another, each representing quite a different kind of treatment. In this way valuable results have been obtained of great practical help in determining which method of cultivation is preferable in any particular instance.

Draining Experiments

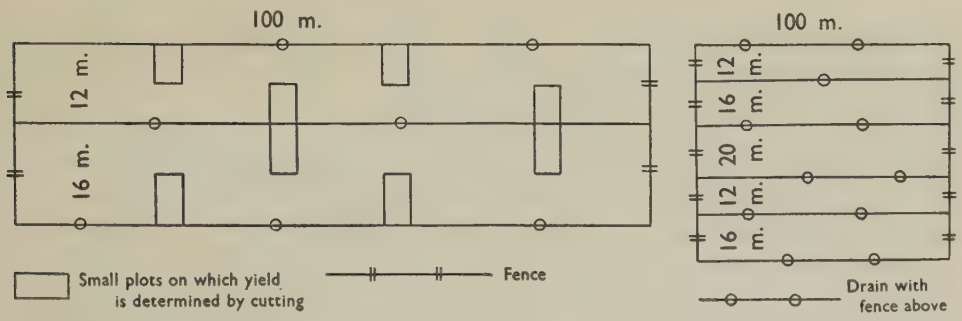
Ditching experiments must be carried out on comparatively large areas. As an example of a draining experiment on pasture, we give in Fig. 2 a plan for such an experiment in Løken, Vestnes, in western Norway.

Here the experiment is concerned with distances between the draining ditches of 12, 16 and 20 m. Each plot of ground to be drained is fenced and cattle are introduced for grazing, alternating in the different plots. The yield of grass is then estimated according to the number of days on which the cattle are grazing in each plot, and the total amount of milk obtained.

In each plot there are smaller cutting plots, as illustrated in Fig. 2. These smaller plots are 4 m. wide and sufficiently long to extend exactly to the centre of the large plot. This last mentioned fact is of great importance and is, of course, an absolutely indispensable arrangement if the test of the yield is to be at all representative of the crop from the whole experimental area in question. The fences around these plots are placed 0.5 m. outside the actual boundaries, which are marked by furrows.

Fig. 2

Plan for draining experiment on pasture at Løken in Vestnes.



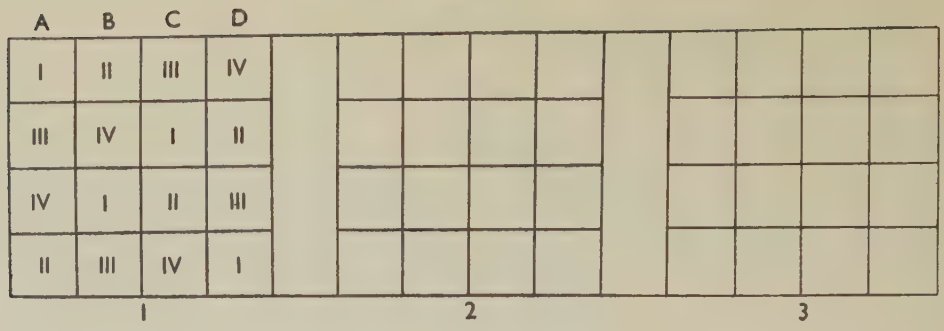
The cutting tests in these drainage experiments are also moved each year to a new place in the area under observation. The crop of grass is cut several times during the year, the yield is determined on a dry matter basis, and botanical analyses are made. The level of the underground water table is measured two or three times each week during the summer, in pipes which are driven down in the centre of each plot.

Fertilizer Experiments

These are based on two different principles and involve : (1) smaller plots from which the crop is removed by cutting ; (2) larger areas where the yield is also determined by grazing. In the case of the smaller plots, it is now customary to have parallel plots which are cropped alternately by cutting and grazing. It is more general, however, to use two and in some cases three parallel plots. If there are two parallel plots, these are cropped alternately by cutting and grazing every other year. If there are three, they are grazed during the first two years and cut in the third year.

An example of how these experiments may be arranged is given in Fig. 3.

Fig. 3



1937 : One cropped by cutting, two and three by grazing.
1938 : Two ,, ,, ,, one ,, three ,, ,,
1939 : Three ,, ,, ,, one ,, two ,, ,,

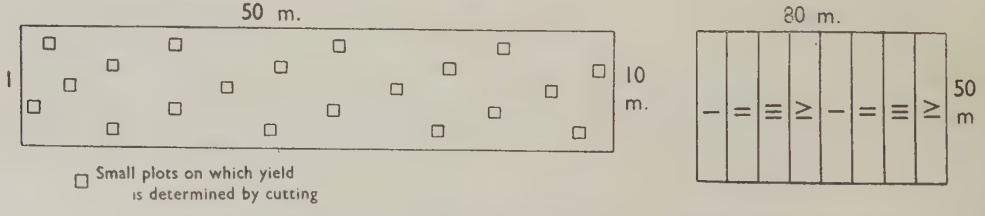
The plots are laid out in sizes of 5 × 4 or 5 × 5 m. Sometimes the entire plots are harvested, but on other occasions border strips 1 m. wide are used, and the plots harvested will then be correspondingly smaller.

The growth is cropped several times during the summer, the yield determined on a dry matter basis, and the botanical composition investigated. Sometimes chemical analyses are also made in order to determine what effect the fertilizers have had upon the quality of the grass. The yield and quality of the crop are judged only in those plots which are cut ; there is no such control in connexion with the plots cropped by grazing. The latter method is used only to determine what effect grazing has on the growth of the grass. It has been shown, for example, that grazing for two years in succession, following a year in which the pasture was cut, maintains almost the same sward as when the pasture is grazed every year.

The larger fertilizer experiments are laid out in plots sufficiently large for the yield to be determined through grazing. Yield data are also obtained, however, by weighing.

In Fig. 4 is a plan of an experiment on increasing amounts of nitrogen which is being carried out at the Pasture Experiment Farm of the Royal Norwegian Agricultural Society.

Fig. 4



Plan for fertilizing experiment (increasing amount of N) at the Pasture Expt. Farm, Apelsvoll.

FIG. 5.—Experiment on increasing amounts of nitrogen, at Apelsvoll Pasture Experiment Farm.

I. Basic Fertilizing
II. 1 + 1 N
III. 1 + 2 N
IV. 1 + 3 N

Every number is repeated twice and the whole experiment has therefore a total of eight fertilizing plots. For grazing purposes four flocks of sheep are used. There is one animal group for each treatment and each flock grazes in the two plots of the same treatment (the group system). The flocks of sheep graze alternately in their two plots, the number of sheep in each flock varying from time to time during the summer, according to the number that can be pastured adequately. The live weight increase of the animals is carefully noted and the consumption of grass is calculated on the basis of fodder units, according to the system worked out by the Assoc. of Agricultural Researchers in the Northern Countries for the maintenance and growth of these animals. The yield of the two plots, which are grazed by the same flock of sheep, is calculated on the basis of number of grazing days.

These experimental areas also contain small cutting plots, from which the yield is determined by weighing. There are twenty such cutting plots, 1 sq. m. in size, within each. The total area of these cutting plots therefore amounts to 20 sq. m. As each of these large grazing plots covers 500 sq. m., the fenced portion amounts to 4 per cent of the total area.

These experiments on cutting plots are moved each year, but are always kept in the same place for one complete summer. The plots are cut four times during the summer ; this cutting is done with scythes when the grazing of the surrounding plot has been completed. The small fences which have enclosed the cutting plots are removed for each cutting. The grass is weighed immediately it is cut and the dry matter content determined. Ten per cent of the grass crop from the plots is taken for botanical analyses and separated into grass, clover and weeds.

The chemical analysis of the samples of grass and clover are made separately, samples from all cuttings and plots of each treatment being mixed, so that one analysis of clover and one of grass is made each year. The samples which have been set aside for analyses are mixed after they have been weighed in proportion to the size of the crop in each of the cuttings and in each of the two plots. The chemical analysis includes complete fodder analysis, and the amounts of P, K and Ca in the ash are determined.

On the basis of the digestible values (percentages) which have been found in grasses at the same stage of development in the Institute of Animal Nutrition, Royal Agricultural College of Norway, the grass crop yield is calculated in fodder units. A common feature in these experiments is that the figures for yield calculated in fodder units (based upon the dry matter content and the chemical analysis) become somewhat higher than the figures for fodder units obtained from calculating the yield on the basis of the maintenance and growth of the grazing animals.

Experiments with Species and Strains of Pasture Plants

As new strains are developed from the most important species of pasture plants

it becomes necessary to ascertain their value under the many different growing conditions of our country. At the same time it is of interest to discover the average yield of the different species of pasture plants. Many such experiments have been made in recent years.

Trials with species and strains are carried out by the row method with four or five replications and from five to eight numbers in every experiment. The plots are laid out with narrow strips between the cutting plots, the width of these being so adapted that the whole plot can be cut in one swath with the mower. As a rule, the cutting plot is 1.1 m. wide and 10 to 12 m. long. All species of grass are seeded in a mixture with white clover, and the white clover strains are sown with *Poa pratensis*.

The experiments are made on parallel plots which are cropped alternately by cutting and grazing every other year. The yield is determined only in the plot from which the crop is taken by cutting in any particular year. These plots are cut with a mower and the process is repeated each time the grass has reached a height suitable for grazing. This generally means that three or four cuts are made every summer. The grass is weighed immediately after cutting, and samples are taken both for botanical analysis and for the determination of dry matter content.

In the botanical analysis a record is made of the quantity of species sown, in addition to other harvested plants and weeds. In this way, it is possible to determine the amount of yield in the form of dry matter produced both by the strain under observation and the species which grow in combination with it. These experiments on different strains are continued for six to eight years.

In his investigations in connexion with the breeding of pasture plants at the Agricultural College of Norway, O. Nissen uses the plan described by A. W. Hudson in the Herbage Publication Series Bulletin No. 11. The technique of experiments with different seeds mixtures for pasture is similar to that used in experiments with strains and species of pasture plants.

Determination of dry matter. As has already been mentioned, the dry matter content is determined in the grass crops taken from the experiments. This determination is made on the Pasture Experiment Farm of the Royal Norwegian Agricultural Society in the following way. A sample is taken of the grass when it is cut. The samples weigh from 700 to 1,000 grm. They are placed in bags made of thin linen cloth, for instance, Printers (P. 74), each bag being about 60 × 40 cm. in size. The weight of the samples in a newly-cut condition is determined by weighing in the field immediately after cutting, and they are then dried in an electric drying cabinet. This cabinet holds about eighty samples of the size mentioned above. It is about 1 sq. m. in section, 2 m. in height, and contains eight shelves of fine mesh wire-netting, placed one above the other. Under the cabinet is a bracket, upon which is placed a 10 kw. electric heater. An electric fan blows the air over the heater and through the cabinet, while another fan on the top draws the air out of the cabinet. There is also a relay switch and a thermo-regulator.

When the cabinet is filled with samples and both fans are working, the temperature inside the cabinet is about 30 to 40°C. above that outside. The thermo-regulator is set in such a way that the current is broken as soon as the temperature inside

reaches 60°C. A bunch of eighty samples can in the course of 10 or 12 hours be dried down to a water content of 10 per cent. When the samples have reached this degree of dryness they are taken out and weighed. Immediately after this weighing, the water contents are determined by the ordinary electric-thermostat. For this purpose only small samples of about 10 grm. are used.

Pasture Control on Private Farms

In order to obtain some information of the extent to which pasture cultivation is an economic proposition under the many different conditions existing throughout the country, several pastures on private farms have been controlled during the past twenty years. The aim of this control is to obtain an idea of the average yields of these pastures and the expenses incurred in establishing and maintaining them.

The amount of the yields is judged on the basis of the total number of grazing days for each animal, their live weight increase, and the milk produced on the pasture during the course of the summer. Such data are noted on a questionnaire specially prepared for this purpose. On this basis the yields are calculated in fodder units according to the standards set by the Assoc. of Agric. Researchers in the Northern Countries. The quantity of fodder which is used to supplement the pasture is deducted from the calculations of the fodder consumption in the pasture time. The animals are weighed just before they are brought on the pasture, and again ten or fourteen days after they are taken to the stables in the autumn. The increase in weight is calculated on the basis of the difference between the two weighings and the calculation of maintenance fodder is based upon the mean of the two yields.

The expenses covering fertilizer work and fencing are included, as well as the interest and amortization in connexion with the cultivation of the pasture and the interest on the value of the ground. Furthermore, the pastures must carry their share of the ordinary running expenses of the farm. In this way it is possible to calculate the cost of production of pasture grass. The same pastures are generally kept under observation for periods of at least five years in succession.

Haakon Foss **Norway**

TECHNIQUE OF GRASSLAND PLOT AND FIELD TRIALS IN NORWAY METHODS OF MEADOW EXPERIMENTS

Meadowland comprises about seven-tenths of the total area of agricultural land in Norway ; of this meadowland area permanent meadows on uncultivated ground constitute about one-fourth. The duration of leys in cultivated meadows varies considerably. In districts where cereal cultivation is extensive, such as in the south-eastern part of the country and in Tröndelag, the leys are of about four years' duration ; in the far north and in the higher mountain valleys they are generally of longer duration. There is, however, a distinct development towards shorter leys, but those of less than three years' duration are rare.

Problems connected with hay production which have been regularly dealt with in our experiments are : comparisons of different species, strains and seeds mixtures, various seeding rates, different nurse crops, the best time of cutting, and questions concerned with the use of fertilizers. Other problems are investigated locally and occasionally.

The methods used in meadow experiments in Norway vary quite considerably according to their purpose and to local conditions. The feature common to all is, however, that relatively small plots and many replications are used.

In experiments with different species, strains and seeds mixtures, the size of plot generally varies between 16 and 20 sq. m., but may sometimes be as small as 10 or large as 25 sq. m. Border belts between the harvest plots are seldom used. In fertilizer experiments which are to continue after the meadow is ploughed up, the plots as laid out generally vary between 24 and 30 sq. m. in size, but as in this case border belts of about 1 m. in width are used, the harvest plots are 15 to 20 sq. m. In short duration fertilizer experiments on meadows, however, smaller plots, 12 to 16 sq. m., without border belts are used. The plots are generally approximately square but long, narrow plots are sometimes used, especially in nurse crop experiments. In trials with different species, strains and seeds mixtures, plots 3 $\times$ 4 m. or 4 $\times$ 5 m. are much more common.

The number of treatments or links involved in each experiment varies widely, but an attempt is made to keep it as low as five or thereabouts. The plots are generally arranged according to the checker-board method, with as many parallel plots as there are treatments. The links and parallel plots are generally spread systematically over the field. A common scheme for meadow experiments is shown in Fig. 1, in which the treatments or links are indicated by small letters.

For the preliminary testing of breeding material and other large numbers of samples, the standard or check-plot method is widely used, frequently in connexion with long plots laid out in rows, with the check-links placed on every third to fifth plot.

The herbage seed is usually sown together with a cereal (generally barley or spring wheat) as a nurse crop. The grain is sown first in the usual way, to be followed by the herbage seed which is worked into the soil by means of a light harrow (Korsmo's weed harrow). Finally the field is rolled. At the outer corners of the plots, poles about two feet long are driven into the soil and the border lines are then marked by furrows, which are renewed every spring.

The observations made in the first year on germination and establishment of the sward are recorded in the autumn, and in subsequent years the density of the sward is estimated every spring in order to ascertain the plants' persistency through the rigours of winter.

Fig. 1.

	A	B	C	D	E	
1	a	b	c	d	e	1
2	d	e	a	b	c	2
3	b	c	d	e	a	3
4	e	a	b	c	d	4
5	c	d	e	a	b	5
	A	B	C	D	E	

The fields are cut with a scythe and the fresh crop from each plot is immediately weighed separately ; for this purpose a wooden frame with wire netting and a steelyard scale are used. Two men lift the scale and burden with a bar, and one of them sets the scale. The result of the weighing is noted in the appropriate place on a harvesting map. The weight of dry hay is generally ascertained by drying small samples of the crop. When the crop has been cut and weighed, a representative bunch of plants about 1 kg. in weight is taken out, carefully weighed, bound, marked with the plot number and dried under cover. The bunches are generally placed in an open, airy place in an outbuilding on the farm ; artificial drying is not generally used. When quite dry the bunches are weighed again, and the loss in weight is then used to determine the weight of dry hay from the plot. In experiments where the plots are very small, and also in time of cutting experiments, the whole crop from the plot is sometimes weighed again after being dried on frames.

Botanical analyses. Botanical analyses are generally made in experiments with different species, strains and mixtures and in time of cutting trials. For this purpose a representative bunch of plants is taken from the newly cut crop of each plot. In more important cases the work of identification and separation is done on fresh plants, but most frequently the bunches are laid aside for later examination. Sometimes the same samples are used both for the dry-hay determination and the botanical analysis. Completeness of the division into botanical fractions will vary according to the purpose of the experiment. Only in special cases do we go so far as to identify and separate all the component species. In ordinary crop experiments it is considered sufficient to divide the samples into clover, timothy, other grass species and weeds. In experiments with seeds mixtures, however, more complete analyses are frequently taken in order, at least, to support and control the estimation by survey. Each fraction is tied in a separate bundle and is marked and dried uniformly before it is weighed. On this basis the botanical composition of the crop is then computed.

In fertilizer experiments and often also in many other types of experiment, the botanical constitution of the sward is estimated by survey just before cutting. We generally find that such an estimation gives fairly accurate results if made by a well-trained person. Both in this and in the analytical method, the results are given in the form of the percentage of the constituents in the dry hay crop.

Chemical analyses. Chemical analyses of hay crops have so far been used to a rather limited extent. In connexion with the investigations to discover the best time for cutting, which have been carried on according to a general plan at all our experimental stations, however, complete analyses of nutritive value have been made on the majority of crops. Furthermore, part of this material is used for digestibility trials on live animals at the Institute of Animal Nutrition of the Agricultural College of Norway. These investigations on the feeding value of hay crops are also carried out more intermittently with less well-known species and with crops grown in particular localities. Elementary ash analyses are also made to some extent in connexion with the more important fertilizer experiments, especially on moorland. The chemical analyses for nutritive value generally include the following particulars: dry matter, crude protein, true protein, fat, N-free extracts, fibre and ash. The digestibility of the protein is determined by treatment with pepsin-HCl (if not by experiments on animals).

The duration of the meadow experiments varies greatly. Clover and timothy leys are generally maintained for three to five years, although the period in the north and in the mountainous valleys may frequently extend to six or seven years. The fields are generally fertilized every spring with a moderate amount of complete artificial fertilizer. If a second crop is expected, some nitrogen is applied after the first cutting. In the southern districts and also in the lowland valleys, two crops are generally cut each year, the first in June or the first half of July, and the second in September. In the northern districts and in the mountainous valleys, generally only one crop of hay is taken in July. When a second crop is taken, a somewhat simplified method is adopted in determining the weight and composition.

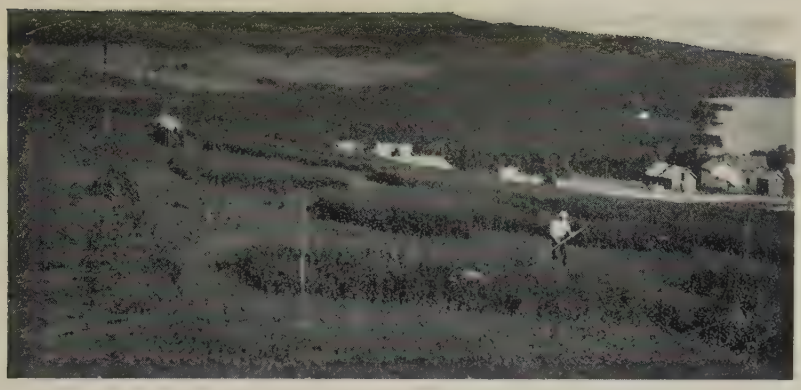


FIG. 2.—Meadow experiment at the State Experiment Station for Mountain Valleys, Löken in Valdres.

FIG. 3.—Comparative yields from a fertilizer experiment on meadowland.

In the preparation and explanation of the results, particular stress is laid upon the yield of dry hay, which is regularly expressed in kg. per dekar (1,000 sq. m.). Figures of fresh weight and drying loss are, however, usually also given. In connexion with some types of experiments, the yields of clover, grasses and weeds are often calculated separately. When the results of chemical analyses are available as a basis, the feeding value of the crop is generally given in Scandinavian fodder units per dekar. Furthermore, the amount of digestible protein, both per fodder unit and per dekar, is often stated, together with the amounts of other nutrients when suitable data are available. In order to control the uniformity of the field and the reliability of the statistical material, the mathematical methods introduced by Knut Vik and R. K. Kristensen are mostly used. The calculation of experimental errors is being made to an increasing degree, but not as yet in all experiments.

The methods described above are in common use in the work of the experimental farms, but local meadow trials are also carried out under the supervision of the State experiment stations in the majority of the rural districts. These are, however, smaller and less complicated. The number of links in each experiment is mostly four or five, and the number of parallels the same or less. Dried bundles are used to some extent in determination of the weight of dry hay, but frequently the fresh weight is regarded as sufficient. Botanical analyses are seldom undertaken, but a rough estimation should generally be made, the differentiation being limited to legumes on the one hand, and grasses on the other. To the farmers who carry out such experiments, seeds and artificial fertilizers are sent from the experimental farm in the proper proportions and marked in a manner corresponding to each plot in the test, together with printed or mimeographed directions and maps. The work is done by the farmer—the " host " of the experiment—either alone or with some assistance from an agricultural adviser in the district. The harvest maps, notes and sometimes samples of the crops are sent to the State experiment station concerned, where they are studied and finally worked into a report for publication.

Henrik Bögh **Denmark**

METHODS OF GRASSLAND ANALYSIS IN DENMARK

At the end of the last century Danish farm management was subjected to a considerable change, after which animal husbandry and consequently also the production of forage crops acquired much greater importance than hitherto. This involved a greater demand on the grassland areas, and work designed for their improvement and more rational cultivation was commenced.

In this work grassland analyses have played an important part. An examination of the plant cover may serve different purposes. The main object was to arrive more or less directly at an expression of the numerical occurrence of the different species and their proportion by weight of the crop. The methods used in Denmark were as follows :

(1) P. Nielsen's method. Turf analysis
(2) Raunkiaer's method
(3) Botanical weight analysis

The Grassland Analyses of P. Nielsen

As part of the efforts to improve the grass fields, grassland analyses were commenced by P. Nielsen in the 70's of last century. For a number of years he made regular examinations of the composition of the plant cover of ordinary rotation grass fields on a large number of farms. These examinations, which were among the first of their kind, became of great importance to the development of rational grassland management in Denmark, and have ever since been considered one of the fundamental efforts to improve the grass fields ; in addition, they are a classic example of the use of grassland analyses in this work.

P. Nielsen's attention was directed more particularly to the sowing of grassland. A complete control of the seed sown was arranged, and by examinations of the composition of the plant cover in the seeding and subsequent years, the growth of the individual species and their contribution to the yield were followed. Nielsen tried to discover the number of plants per unit area which should be aimed at, the species which were most suitable under different conditions, and finally how the seeds mixture should be composed in order to obtain a suitable plant population. In such work grassland analyses had to play a prominent part. Nielsen used a method elaborated by himself, the object of which—in accordance with the purpose—was to determine the *number* of plants and the total *weight* of each species per unit area.

P. Nielsen's method—turf analysis. At the time of field cutting, a number of turf samples—most frequently ten—were taken for analysis from regularly distributed places where the plant stands were considered to be typical and to give a true picture of the crop as a whole. An accurately measured frame (area $= 0.11$ m^2) was pressed in the soil and the turf carefully removed. As a rule all ten sections were grouped

together and the plants counted collectively. Each individual plant was carefully lifted from the bottom and, after cutting off 1 to 1.5 in. above the soil surface, all plants of the same species were weighed immediately. This separation of each individual plant was a comparatively easy process in the seeding year, but very difficult in later years when the tufts became entangled, and the individual plants spread more or less according to their habit of growth. There must be a certain latitude in estimation and some species have produced an increasing number of plants during the years.

On the other hand, it is possible to make the weight determination with a high degree of reliability. In weighing crops from larger areas for comparison, Nielsen showed that, by means of the turf analysis, it was possible to obtain an idea of the total yield of the field. In later examinations, E. Lindhard tested the method further and found the reliability of the yield determinations to be comparatively good. Turf analysis, however, shows a slight tendency to give excessively high yield figures, which is naturally explained by the fact that the bottom grass is removed to a greater extent than by cutting with a scythe, and furthermore by taking turf samples the bare spots in the field are more or less avoided.

The reliability of the picture of the plant cover obtained by such analysis depends very much on the *sampling*. By taking portions from all parts of the field, one-sided sampling thus being avoided, the mutual agreement between the individual samples may serve to illustrate the reliability, while on the other hand systematic sampling errors will remain hidden. Results of a few examinations on the variation between replicate samples are available and data from such material obtained from P. Nielsen's examination are given below. The average of all ten samples was calculated and, for the sake of comparison, also of the first five and the last five samples separately. There appears to be a high degree of uniformity.

Number of plants

	Legumes				Grasses							
	Trifolium pratense	*Trifolium hybridum*	*Trifolium repens*	Total legumes	*Lolium multiflorum*	*Lolium perenne*	*Festuca elatior*	*Dactylis glomerata*	*Arrhenatherum elatius*	*Phleum pratense*	Total grass	Total
Average of Nos. 1–10	34.6	14.0	4.9	53.5	2.7	6.7	3.3	9.3	2.5	10.8	35.3	88.8
Do. 1–5	35.2	14.6	5.6	55.4	2.6	6.0	2.8	9.0	3.2	9.4	33.0	88.4
Do. 6–10	34.0	13.4	4.2	51.6	2.8	7.4	3.8	9.6	1.8	12.2	37.6	89.2

Later Lindhard examined this question in more detail by selecting twenty turf samples in a systematic way. The results obtained are recorded below, figures being given only for legumes and grasses and their total.

	Number of plants			Weight in grm.			
	Legumes	Grasses	Total	Legumes	Grasses	Weeds	Total
Average of 20 sections	17.4	26.4	43.8	48.6	88.4	12.0	149.0
Av. of 10 sections (based on above 20)							
a. Even numbers	14.8	24.9	39.7	36.6	79.1	5.5	121.2
b. Odd ,, ...	20.0	27.8	47.8	60.5	97.4	18.5	176.4

Ten turfs gave a bad picture of the crop. Whether twenty are sufficient will depend upon the accuracy of the results required. The averages for twenty samples present a certain degree of unreliability. If this is indicated by the standard error, the average number of plants and their average weight for twenty sections will be 43.8 ± 3.85 and 149.0 ± 11.64 respectively. That is, by repeating the examination of twenty turfs selected in the same way, the average number of plants and the average weight for each turf in two out of three cases probably will appear to lie within the limits 39.95 to 47.65 and 137.36 to 160.64 respectively. If greater accuracy is desired, either the number of turfs examined or their size must be increased.

The first mentioned material from Nielsen's examinations seems to indicate that five samples will be sufficient to obtain a reliable picture of the crop; this is explained by the fact that he was concerned with very uniform and homogeneous material and that samples were selected from places with a typical growth of plants.

E. Lindhard's examinations. P. Nielsen finished his grassland analyses about 1890 and in 1905 the work was taken up again by the Danish State Experimental Service in co-operation with the Agricultural Association in Jutland. The study, directed by E. Lindhard, was on the whole carried out in the same way and with the application of the same method as before. In addition, however, a larger number of experimental plots was included and hay and nitrogen determinations were made of the sections to be analysed. As already mentioned, Lindhard made further tests on the reliability of the method. For the rest it has been a matter of extending the examinations to include more varying conditions; in particular the examinations were concerned with grass fields on comparatively light soils, which in some cases suffered from lime deficiency and were in a different condition regarding nutrients.

Lindhard also examined older permanent pastures which were used in different ways during the summer. By means of analyses immediately before each cutting, the contribution of the individual species to the yield throughout the summer was ascertained.

The turf analysis has also been used in other examinations in a more or less modified form. Almost simultaneously with Lindhard, K. Hansen and M. L. Mortensen commenced a similar work on Sjaelland, using a method which was a modification of that adopted by P. Nielsen; the area was larger, but the pasture and the objects were identical with those of Nielsen.

Examinations made by the Grass Field Sections. Later grassland analyses were continued, particularly by the Agricultural Associations, which appointed Grass Field Sections; these examined the grass fields of a large number of farms with varying soil (loams, sands, bogs and marshes) and also under a range of moisture and soil reaction. The object was in part to pass judgment on the condition of the grass fields and also in part to throw light upon the occurrence and distribution of the different plant species under varying conditions and in fields of different ages.

In addition, analyses were made in connexion with various kinds of cultivation work, namely, reclamation of boggy soils, different methods of sowing, manurial trials, etc., as well as with grazing control, in which the yield of a certain number of pastures was recorded as follows: the increase in weight of the cattle and the milk production were determined and the yield of the pastures calculated on this basis. Further, the plant stands in the fields under consideration were examined.

Raunkiaer's Method

The method used in these examinations was adapted from the investigations of plant formations. About 1910 the Danish botanist, C. Raunkiaer, elaborated his analysis method, the object of which was to determine the *occurrence* of the different species and their relative *cover*. Numerous small plots were examined as regards the species present and an estimate of the proportion of the area covered by each species was made. The plant stand was characterized partly by the percentage by number of the sample plots where each individual species occurred, and partly by the percentage cover provided by each species. In the grassland analyses the following characteristics were most frequently recorded.

1. Percentage of plots in which each species occurred
2. Main cover, that is, total cover divided by number of plots
3. Maximum cover
4. Percentage by number of plots where more than 25 per cent of the area was covered by each species

In the examinations a stick with 10 semi-diameters was used. The circle comprised an area of 0.1 m^2 which was divided into ten equal portions by the semi-diameters, thus making an estimate of the cover within each portion a comparatively easy matter.

As is obvious, this method does not aim at describing the plant stand by means of the number of species occurring. The occurrence of the species within the plots depends partly upon their number, and partly upon their distribution, and finally also on the size of plants. In this way the occurrence is to some extent an indicator of the composition of the plant cover, but in order to obtain a better expression of the quantitative conditions the species cover was also included. The Agricultural Associations in Jutland have made an examination of the relation between the cover provided by the individual species and their proportion by weight of the plant cover. The percentage cover was determined in twenty plots, after which a botanical analysis of the crop was made from forty small squares, each 100 cm^2 in size; in addition, the number of shoots of each species was determined. The results were as follows :—

Percentage	Number of analyses	*Trifolium repens*	*Vicia cracca*	*Lolium perenne*	*Poa pratensis*	*Poa trivialis*	*Alopecurus pratensis*	*Dactylis glomerata*	*Cynosurus cristatus*	*Bromus mollis*
Cover	20	0.3	0.3	6.0	2.4	0.5	0.1	42.5	0.3	1.0
By weight	40	0.5	0.4	6.5	2.0	0.2	0.5	51.0	0.1	0.7
By number	40	1.0	0.5	9.0	4.0	0.6	1.0	24.0	0.1	1.2

Percentage	*Holcus lanatus*	*Festuca rubra*	*Agrostis alba*	*Anthoxanthum odoratum*	*Trisetum flavescens*	*Hypochoeris radicata*	*Hieracium pilosella*	*Leontodon autumnale*	*Achillea millefolium*	*Plantago lanceolata*	*Taraxacum officinalis*
Cover	6.0	2.4	2.0	0.2	1.0	9.5	2.0	7.0	3.0	6.5	7.0
By weight	5.0	2.7	2.0	0.1	0.5	8.0	2.0	2.4	3.0	7.0	6.4
By number	7.4	8.3	3.8	0.4	0.8	5.3	3.2	11.0	6.0	6.4	6.0

The figures for cover and weight compare reasonably well and the former give a good idea of the relative importance of the individual species. On the other hand, the number of species will be a bad criterion in this respect, since even in the grass fields the size of the different plants varies too widely. The number of shoots is considered to be a better criterion, although the examination reported indicates that it will not always give a good idea of the contribution of the individual species to the yield.

As a rule ten to twenty plots were used in this study. No material which permits judgment of the *reliability of the average result* has been published, but it is often mentioned in reports that ten plots are sufficient only when the crop is very uniform and homogeneous, and that twenty plots will give a satisfactory result when the plant stand is more variable. The conditions may probably be considered as similar to those in turf analysis.

Botanical Weight Analysis

The botanical weight analysis, which has been used to a lesser extent in Danish grassland research, was carried out in the following way: before cutting, small

limited areas were cut off or samples were taken after cutting from several places in the crop harvested. The samples were united and average samples for analysis were obtained. At this time the control of the number of plants was dropped and attention given only to the weight composition of the crop. In this particular respect the method resembles the turf analysis, but the two methods present various differences. By selecting samples from the crop of plants harvested, the bottom grasses will not be represented so well as in the turf analysis. The percentage by weight of the composition of the crop will therefore vary somewhat according to the method used. In this respect turf analysis approaches more closely to removal by grazing. Furthermore, in the botanical weight analysis, an indeterminable residue will always be left which, especially when the analysis is being made of a hay crop, may be comparatively large. The turf analysis does not present any difficulty in the identification of species.

The selection of samples for botanical weight analysis must be made from several parts of the field and in such a way as to ensure that the bottom grasses, as well as the taller plant species, are represented in their proper proportions in the average sample. By taking a few samples only, accidents would play too prominent a part. The sampling reliability has been examined by Frode Hansen, who took from each of two fields twenty average samples for analysis which included the separation of grasses, legumes and weeds. The content of leguminous plants in the two fields was 15.6 and 51.9 per cent respectively. In the first case, the standard deviation of a single sample was 2.10 per cent and in the other 2.83 per cent. A deviation of about 5 per cent from the actual average will occur comparatively rarely if only one analysis is made, and by using duplicate samples the uncertainty is reduced by $\sqrt{2}$. Here the accuracy desired must be decisive as regards the number of samples to be selected.

As knowledge of the growth of the individual species and their importance in the grass cover under different conditions became enlarged, grassland analyses have been thrown more and more into the shade and endeavours are now made to an ever-increasing extent to solve the different questions through actual *experiments*. In the case of grass fields, this means experiments on seeds mixtures, strains, manures and treatment, in which botanical analyses must always play a part. Grassland analyses are, therefore, made almost entirely in connexion with cultivation trials in Denmark and thus the botanical weight analysis will be mainly used. The procedure may vary somewhat in individual cases, but as a rule the analysis is made of duplicate samples of 1 to 2 kg. each, selected after cutting, and only in rare cases is the sampling made by taking small sections before cutting. Most frequently the work is limited to the separation of legumes, grasses and weeds and the hay determination of these components.

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THE TECHNIQUE OF EXPERIMENTS WITH STRAINS AND SEEDS MIXTURES

Experiments with meadow and pasture plants were one of the first tasks to be studied by the Danish Experimental Department, as P. Nielsen, Government Adviser, had already in the 70's of last century carried out comparative experiments with different species of legumes and grasses, and with various samples of seed of the most important plant species constituting the ordinary seeds mixtures for the grass fields. At that time the bulk of these samples came from abroad, as only small quantities were then produced in Denmark. The main object was, therefore, to discover the countries which could supply seed most adapted to Danish conditions and giving the highest yield.

P. Nielsen proved at a very early date that, on the comparatively few occasions when it was possible to include seed of Danish origin in the experiments, such seed very often gave a higher yield than foreign seed. This provided the impetus for the breeding in Denmark of meadow and pasture plants, some seed growers beginning to produce, by breeding, strains with higher yields. Since that time seed growing and herbage plant breeding have been further developed, with the result that the experimental work with meadow and pasture plants is now confined to comparisons between the different Danish strains and to tests on the best composition of seeds mixtures for the different soils with a view to utilizing the grassland for grazing or hay production.

The experiments are made chiefly by the Government Experimental Stations, while the agricultural societies occasionally carry out experiments for the purpose of supplementing those undertaken by the Government Experimental Stations, or they take up particular problems for investigation, for example, experiments with seeds mixtures.

Experiments with Clover and Grass Strains

The Government Experimental Department for Plant Culture has prepared fixed rules for the carrying out of strain trials with herbage plants. As the experiments undertaken have proved that leguminous plants, particularly red clover (*Trifolium partense*) and white clover (*Trifolium repens*), have a decisive influence on the yield of meadows and pastures and on the feeding value of the crops, the rules dealing with strain experiments lay particular stress on the testing of these clovers.

The experiments with red clover generally extend over a six-year period, the clover, for example, being sown in 1938, and the experiments being then continued with the same strains in 1939 and 1940. As each experiment is down for two years (in addition to the seeding year) for the purpose of determining yield, the trials may be completed and a report published after the harvest in 1942; a new period would then begin in 1944.

The strain experiments with white clover likewise comprise a period of six years, but generally with a single sowing, and yield experiments a period of five or six years. The other leguminous plants are not included in regular experiments, although these are undertaken when it is considered advisable, that is, when the Experimental Station learns that new strains have come forward which should be tested.

Regular experiments with grasses are confined to perennial ryegrass (*Lolium perenne*), timothy (*Phleum pratense*), meadow fescue (*Festuca pratensis*) and cocksfoot (*Dactylis glomerata*), other species being included only when considered necessary. The experiments with grasses also cover six years, but the species are sown only for two years and yield experiments over a two-year period are undertaken after each sowing.

When a series of experiments is to be started, it is announced by the Experimental Department in the agricultural papers, and the owners of strains are invited to enter them for testing. An individual entering a strain for experimental treatment is required to prove his ownership of the strain, and must have a certain further minimum quantity of stock seed in his possession. The owner of the stock seed agrees, if his strain becomes recognized by the Experimental Department at the completion of the experiment, to sell it in the open market to other seed firms which may desire to purchase it for further propagation.

Owners of the stock seed must supply seed for the experiments free of charge, but otherwise the trials are undertaken without any expense on the part of the owners. The experiments are laid down at seven or eight experimental stations in different parts of the country, thereby ensuring that the strains are tested under different conditions of soil and climate. The plan of experiment is identical at all the centres. When the stock seed is received from the owners it is analysed to determine its germinating power, in order that the quantity sown may be adjusted in accordance with germinating capacity.

As a rule, the maximum number of strains at a particular experimental centre does not exceed nine, but in exceptional cases up to twelve strains may be included. In addition to the new strains which have been entered, an old well-known strain is used in the experiment and, at the discretion of the station, a few foreign strains may be included for comparison with the Danish.

The experimental leys are sown under cover crops, for which stiff-strawed spring varieties of oats or barley are used. The cover crop is sown at its normal time, that is, either at the end of March or the beginning of April, according to circumstances. The clover and grass seeds are sown as soon as possible, and in any case not more than a week later. Both the cereal and the clover grass mixture are sown in drills. The cereal is sown crosswise in the field. In order to ensure that the clover and grass seeds sown are uniformly spread and approximate as closely as possible to the fixed quantity, the seed is mixed with coarse-ground maize in such a proportion that the aggregate quantity of maize and seed sown will be about 100 kg. per ha.

In the clover experiments an endeavour is made to compare the strains as

closely as possible under the same conditions as those in which the clover is used in grass mixtures. The clover in strain experiments is, therefore, sown mixed with grass. In determining the quantity to be sown, however, it has to be borne in mind that the clover should always be dominant in the crop, while the grass should be only a reserve. Among other things, the grass serves to keep down weeds, should the clover be weakened at any time by drought, disease or other causes. In the case of red clover leys, the usual seeding rate is 15 kg. red clover, plus 3 kg. perennial ryegrass per ha. In experiments with white clover, the most common mixture is 6 kg. white clover, plus 15 kg. perennial ryegrass per ha. In the grass experiments, the grass species are sown without any admixture of legumes. In this case, therefore, a deviation is made from the general practice, as even a small admixture of clover in the grass will, under ordinary conditions of growth, give a yield in which the clover dominates, at least in the first harvest year ; as the difference in yield between the superior grass strains is rather slight, it would be difficult to determine it accurately in a mixed crop of clover and grass.

The experiments are carried out according to the " row method " with narrow plots placed crosswise in the field and as far as possible in a single row. The size of the plots is generally 10 × 2 m., and they are surrounded by an unsown belt, 20 cm. wide, which is kept cleaned during the whole experimental period. The strains to be tested in the experiment are sown in numerical order side by side, and are repeated eight times in the same rotation. Two or three auxiliary plots are arranged at the end of the experimental field, but their crop is not considered in the calculation of the average yield of the strains ; they are used, however, in the equalization calculations made to eliminate discrepancies due to differences in the quality of the soil. Some of the trials are designed with twelve replications, in which case the experiment is divided into two, each half comprising six replications. In one half of the experiment the crop is harvested three to four times in the course of the summer, being cut the first time for hay when flowering begins ; the plots in the second half of the experiment are cut five or six times.

The crops are usually cut with a grass mower equipped with a large pan behind the cutting bar for collection. Scythes are sometimes used, however. The green crop is weighed immediately after cutting and two samples, each 10 kg. in weight, are taken from each experimental link for determination of dry matter content ; two samples, 1 kg. each in weight, are taken for botanical analysis. The samples for the determination of dry matter content are immediately cut into chaff. This is mixed carefully and a sample of from 400 to 500 grm. is taken from each sample of chaff, which sample is then dried in the drying kiln down to a constant weight. The yield of dry matter in a particular strain is determined. The samples intended for botanical analysis are immediately separated into clover, grass and weeds ; the samples are then dried in the laboratory. The botanical composition is determined by weighing the separate components of the samples when in an air-dried condition.

Determination of the yield is generally carried on for two years for red clover and grass strains, and in computing the results of the experiments, the aggregate average yield of dry matter of the strain in two years of growth is taken in all the

experimental centres. The yield figures which determine the order in which the strains are to be placed are obtained from the average yield. For white clover strains the results are most frequently compiled in the first two years separately, the next third and fourth years separately, and finally, the aggregate yield in all the experimental years.

When the results of the experiments are published, the strains are placed in their proper order, according to their yield of dry matter. Those strains which give the highest yields are recognized as first-class strains by the Experimental Department and on the sale of seed from such a strain the owner is entitled to add after the name of the strain a Roman figure to denote the number of the experimental series, for example, " Early Red Clover Hinderupgaard I."

Experiments with Seeds Mixtures

The technique employed in connexion with seeds mixture experiments is substantially the same as that described above. These experiments do not, however, form a regular part in the work of the Experimental Department ; a series of experiments of this type has been carried on at intervals when considered desirable.

P. Nielsen undertook experiments with seeds mixtures for many years, testing a large number of species of different leguminous plants and grasses in various mixtures. Proposals for the composition of seeds mixtures for different purposes have been prepared on the basis of the results of these experiments. The type of mixture which has been used most frequently for several years for a two-year ley has comprised many different grasses and legumes ; from 28 to 30 kg. of seed were sown per ha., one-third being leguminous species.

The appearance of Danish strains of herbage plants gave rise to new experiments with seeds mixtures, with the result that the mixtures now used are simpler in composition, containing as a rule from 20 to 22 kg. seed per ha. for a two-year ley ; 40 to 50 per cent of this amount consists of leguminous plants, the balance being two or three grass species.

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METHODS USED IN PASTURE EXPERIMENTS IN FINLAND

Introduction

In a recent account of the methods employed in Sweden for estimating the productivity of grassland in experimental work, Giöbel[3] arranges the methods in four categories in accordance with their use for investigations concerning : (1) botanical composition of herbage ; (2) chemical composition and palatability of herbage ; (3) amount of herbage produced, and (4) amount of animal products obtained.

In regard to investigations belonging to the first category, it should merely be noted that the method whereby the frequency of plants is estimated by means of a scale ranging from 1 to 10 is employed to a certain extent in Finland. As this method, however, is too subjective to give completely satisfactory results, the Pasture Experimental Station adopted some years ago, by way of trial, the quadrat point method evolved by Levy,[5] which possesses certain advantages over the methods hitherto used. It is not our intention here to give a more detailed account of this method, but simply to refer to Levy's own publications. In the near future an account will be published of our experience up to the present in the use of Levy's method in Finland.

Investigations belonging to the second category do not, in our opinion, come within the scope of this article so much as those of the first. In recent years the herbage samples taken from Finnish grazings for chemical analysis have been analysed in accordance with the usual methods by the State Agricultural Chemistry Laboratory at Helsingfors. So far as I know, no studies of palatability have as yet been made in Finland.

Studies belonging to the third and fourth categories may be classed together as investigations on the productivity of grassland, in the former case directly through cutting and weighing the herbage, and in the latter case indirectly on the basis of the animal products obtained on the pasture. The following is an account of the methods employed in both cases in Finland in trials conducted by the State from 1924 onwards.

Direct estimate of productivity. In discussing the methods which may be used for the direct estimate of productivity, reference is again made to the previously quoted article by Giöbel.[3] According to him there may be distinguished, among the ordinary mowing methods and several other cutting methods, some whereby the pasture character of the area may be retained. The general mowing methods are not suitable for long duration experiments in pastures, because the character of the area is changed from a pasture to a hay type by continuous mowing. Giöbel divides the other cutting methods, however, into three categories :

(a) The separation for a shorter or longer time of certain areas within plots, the rest of which is grazed, by means of movable fences (control cages).

(b) The taking of cuts from certain parts of each plot immediately before and after grazing.

(c) The laying out of trials in two or more complete replications, which are alternatively grazed and mown.

Of these the first has been employed in Finland. The size of the control cages is generally 4 × 4, or 5 × 5 m. They are moved to a new place within the same plot after each cut, and, if in the new place there still remains some grass, this is mown before the cage is placed on it. As a rule four parallel cages are employed, but in some experiments the same cage is moved after each cut to a new parallel plot within the same complex. The method is very suitable in the case of an experiment on arable land, but less suitable for experiments on natural pasture land.

Indirect estimate of productivity. This is based upon the determination of the animal products obtained on the pasture, which is done by means of weighing the animals, at least at the beginning and end of the grazing period, wherein the animals' mean weight and live weight increase are determined. In addition, there is weighed the milk, wool, etc., produced on the pasture. On the basis of the weighings, the following calculations are made : (i) number of fodder units* per 100 kg. live weight which the animals have absorbed in maintenance fodder, and (ii) number of fodder units per kg. live weight increase, milk, etc., in production fodder. From the total of the fodder units obtained in the above-named fashion there are subtracted the supplementary rations (concentrates or the like) which may have been given to the animals during the grazing period, also calculated in fodder units. The remainder gives the quantity of fodder units which have been taken up by the animals from the pasture.

In the Report of the Congress of the Scandinavian Agricultural Association for the year 1935, Steensberg[7] gives a detailed account of the norms which are employed for calculating the productivity of pastures in the northern countries. Of the norms described by him, those for cattle were evolved by L. Frederiksen and those for sheep and horses by N. Hansson and H. Isaachsen. In Finland mainly these norms have been employed, although with slight alterations to suit Finnish races of animals in accordance with the results of experiments made by Poijärvi. Charpentier, in making use of the above-named norms, more or less modified to suit Finnish circumstances, employed a method which has been described in a previous article,[1] and of which the following is a brief account.

In the investigation of pasturage problems, where there are two groups of animals, two so-called pasture complexes are necessary, i.e., two pasture areas each containing, for example, four pasture enclosures or plots as nearly uniform as possible. (For each further group of animals an additional similar pasture complex is required.) The experimental plots composing the pasture complexes thus formed should be located so that their relative positions on the experimental fields are such as to distribute possible irregularities in the ground as evenly as possible between the various complexes.

The size of the field depends in the first place upon the class of animals to be

*One Scandinavian fodder unit corresponds to the value of 1 kg. barley. 1.43 fodder units = 1 kg. starch equivalent.

grazed upon it. Suitable animals are, for example, twelve to eighteen-month-old heifers. (The present average weight of the home-bred Finnish heifer is generally about 200 kg.) When grazing such animals in a field comprised of natural pasture, the most suitable area for the enclosure is half a hectare. If the experiment field is situated on arable land, however, an enclosure area of one-third of a hectare is sufficient. The herd should contain at least six heifers, as similar as possible in characteristics.

Since pasture in early summer is in general more productive than in the middle and at the end of summer, the experimental herd usually contains more than six head, the number being reduced during the season as conditions demand. The animals should always be weighed if the size of the herd is altered. Correspondingly larger herds should similarly be placed on those pasture complexes where larger crops are expected than on others. Under this procedure, there will normally be a herd of at least six animals in the field the whole summer, and also one or more beasts in reserve on each pasture complex for a longer or shorter period.

The herbage in the experiment fields can also be disposed of by using, in addition to the regular experiment herd, one or more reserve herds, composed of at least six similar animals. The purpose of these reserve herds is to consume the herbage not eaten by the regular herd. They are put in together with the regular herd for as long a period as the growth of herbage in each case requires. The regular herds are generally grazed on the same pasture complex the whole summer, but if the herbage becomes depleted, some or all of the regular herds may be removed from the field, either completely or for a fixed period. During any intervals when the herds are not grazed on the experiment pasture, they should be kept on pasture as similar as possible to the experiment field in question. In practice, the herbage in the experiment field is generally such that the regular herd grazes throughout the whole summer on all the experiment complexes and, in addition, the reserve herd belonging to the previously mentioned herd grazes each of the complexes for a longer or shorter period from early summer onwards.

The experimental pasture animals are periodically weighed, for example, every ten days, and then on two consecutive days. If the difference between these two results shows a variation greater than 5 per cent, the animals are weighed a third time the following day, and the average of the two weighings nearest to one another is taken as the result. Scales are placed in the field to carry out the weighing. Charts published in connexion with the reports on various experiments show how a drinking place, protective wood, etc., may be arranged in experiment pasture. When planning the experiment field, care should be taken that the total area of wood and lanes is the same on each of the pasture complexes.

Thus, for experiments with grazing animals in Finland the so-called group system described by Klapp[4] has been generally employed. At the State Pasture Experimental Station sheep have also been used, as described by Charpentier.[2] In employing sheep as an instrument for determining productivity, considerably smaller areas can be used than when dairy cows or heifers are employed. With dairy cows it is necessary to have an area of 5 to 8 hectares, so that sufficiently large

groups of animals may be kept on the pasture, and for heifers an area of 3 to 4 hectares is required. The treatments in the above-named case, however, are only two. If, on the other hand, sheep are used as the experimental animals, there is room on an area of approximately one hectare for three to four treatments with four or three parallel replications.

At the Finnish State Pasture Experimental Station a number of experiments of this nature have been carried out from 1935 onwards. In these it has been found that in May and at the beginning of June it is better to use somewhat smaller groups of animals than the normal ten to fifteen while there are night frosts and the growth of herbage in consequence is slow. As soon as the warmth of early summer sets in, the size of animal groups based upon weather conditions and the intensity of grass growth is increased in accordance with the various treatments, after which the groups are again reduced as required during the middle and late summer. Repeatedly altering the groups of animals in this manner may at first sight appear to be unsuitable, but it may nevertheless be appropriate, since the different treatment areas are thereby grazed in the same way in comparison with one another. It is of importance that the various groups, although comprised of a different number of animals, correspond as far as possible with one another in their composition, and it is especially important that in each group the proportion of ewes and lambs be the same, since the weight increase is calculated in a different way and varies considerably in ewes and lambs.

To facilitate the obtaining of uniform sets of animals, groups of special units instead of single individuals can be composed. Stapledon and Jones[6] employ two coupled sheep as a unit. It is to a certain extent easier to find several units of this kind, having the same weight, than to find separate individuals with exactly the same live weight. In analogy with Stapledon's sheep unit we have made use of " sheep family units ", consisting of one ewe and one or more lambs. By selecting at the beginning of the experiment a sufficient number of sheep families of as far as possible the same total weight, and by increasing or reducing the groups by one or more units during the course of the experiment, groups of animals may be made to correspond with one another in their composition throughout the whole summer, although the number of animals within the different groups may not be alike.

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LOCATION OF AGRICULTURAL RESEARCH STATIONS IN NORWAY, SWEDEN, AND FINLAND

Norway

*The postal address of each station is given in parenthesis.

1. The Agricultural College of Norway (Landbrukshøgskolen i Ås), Soil cultivation; breeding of all agricultural crop plants.

State Experiment Stations

2. Møistad (Hjellum st.)
3. Løken. For Mountain Valleys. (Volbu i Valdres)
4. Kjevik (Tveit pr. Kristiansand)
5. Forus (Forus pr. Stavanger)
6. Furenesset (Grytøra i Askvoll)
7. Voll (Moholtan pr. Trondheim)
8. Vågønes (Bodø)
9. Holt (Tromsø)

The main work of the State Experiment Stations Nos. 2 to 9 is experiments with all agricultural crop plants and with cultivation in the various districts in which they are located.

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10. Experiment Station for Moor Cultivation at Mæresmyra (Mære st.) Norwegian Association for Moor Cultivation (Det Norske Myrselskap)
11. State Sheep Breeding Station at Edøy (Edøy) Pasture experiments
12. Pasture Experiment Station at Apelsvoll (Kapp)
    Royal Norwegian Agricultural Association (Det kgl. Selskap for Norges Vel.)
13. Station for Production of Certified Seed and Plant Breeding, Vidarshov (Hjellum st.), Felleskjøpet, Oslo
    Breeding of herbage plants.
14. Hvam Experiment Station (Årnes st.)
    Soil cultivation experiments

Sweden

Centres of the Swedish Grassland and Moor Cultivation Association (Svenska Vall- och Mosskulturföreningen)

1. Alnarp (near Åkarp)
2. Bjärka Säby
3. Linköping and Linköping Branch Station
4. Blombacka (near Skara) and Skara Branch Station
5. Hasselfors
6. Sickelsjö
7. Skultuna
8. Svanå
9. Ultuna (seat of the Association and of the State Agricultural College of Sweden) and Ultuna Branch Station
10. Uddeholm
11. Hofors
12. Nordvik
13. Medstugan (at Duved) in the mountain region
14. Brattby (at Spöland)

State Institutions

Experiment Farms

15. Ugerups (sandy soil) (Kristianstad)
16. Flahult (peat soil)
17. Lanna (clay soil)

18. Experimentalfältet (near Stockholm), where the State Agricultural Experimental Institute is located; in a few years this will be moved to Ultuna where it will be amalgamated with the State Agricultural College

Experiment Farms

19. Offers (at Undrom) and Undrom Branch Station
20. Gisselås (peat soil)
21. Sunderbyn
22. Brännberg

Stations of the Swedish Seed Association

23. Svalöf (Headquarters of the Association)

Branch Stations

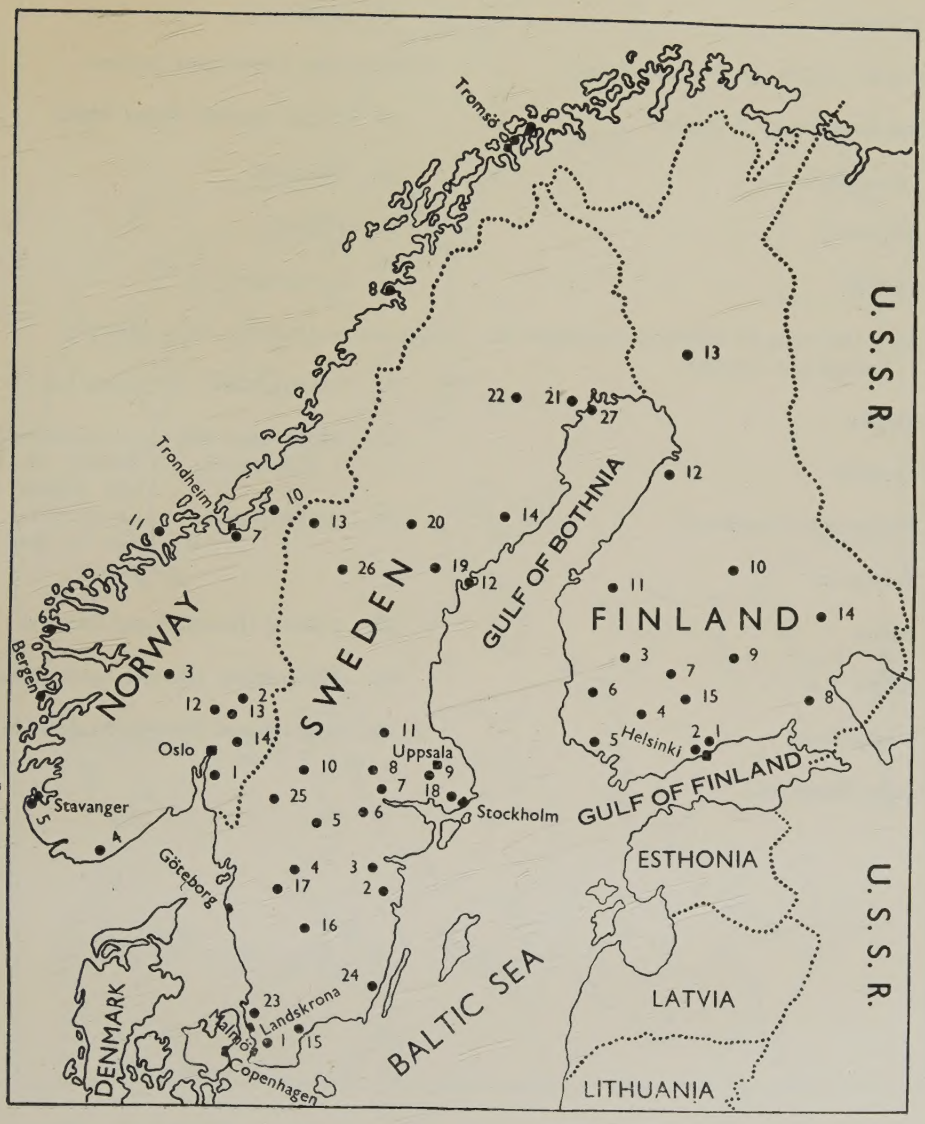
24. Kalmar
25. Varpnäs (near Karlstad)
26. Torsta (Täng)
27. Luleå

Finland

1. Central Agricultural Experiment Station, Tikkurila
2. Plant Breeding Station, Tammisto, Malmi
3. Pasture Experimental Station, Mouhijärvi
4. Plant Breeding Division, Central Agricultural Experimental Station, Jokioinen
5. Horticultural Division, Central Agricultural Experimental Station, Piikkiö

Agricultural Experiment Stations

6. Kokemäki
7. Pälkäne
8. Antrea
9. Mikkeli
10. Maaninka
11. Ylistaro
12. Ruukki
13. Rovaniemi
14. For Bog Cultivation, Tohmajärvi
15. For Bog Cultivation, Leteensuo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GOVERNMENT STATIONS FOR CROP CULTIVATION AND PRIVATE STATIONS FOR PLANT BREEDING IN DENMARK

1. Seed Testing Station
2. Soil Laboratory
3. Experiment Station for Plant Pathology

Agricultural Experiment Stations

4. Virumgaard
5. Aakirkeby
6. Tystofte
7. Abed (Breeding by Farmers' Association in Lolland and Falster)
8. Aarslev
9. Tylstrup
10. Fossevangen (Peatland)
11. Studsgaard
12. Borris
13. Askov
14. Lundgaard
15. Ribe (Marshland)
16. Højer (Marshland)
17. Jyndevad

Horticultural Experiment Stations

18. Virum (Culture under Glass)
19. Blangsted
20. Hornum
21. Spangsbjerg

Private Stations for Plant Breeding

22. Taastrupgaard (*Trifolium* Ldt.)
23. Øtoftegaard and Toftøgaard } Co-operative Wholesale Society of Denmark and Danish Farmers' Co-operative Association for Seed Production.
24. Roskildegaard } Co-operative Wholesale Society of Denmark and Danish Farmers' Co-operative Association for Seed Production.
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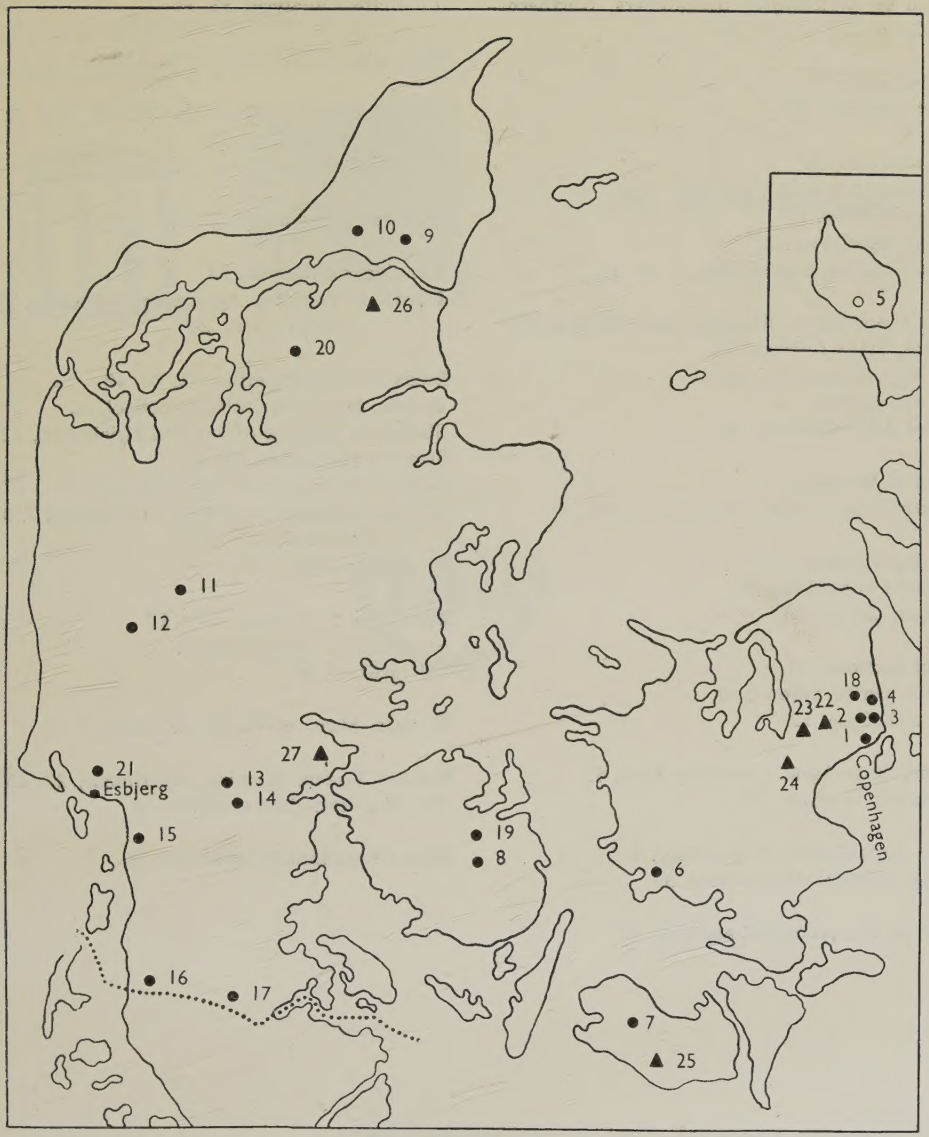
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